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by Michael Tjepkema, Russell Wilkins and Andrea Long

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...	not applicable
0	true zero or a value rounded to zero
0^s	value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p}	preliminary
^{r}	revised
x	suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E}	use with caution
F	too unreliable to be published
*	significantly different from reference category ($p < 0.05$)

Cause-specific mortality by education in Canada: A 16-year follow-up study

by Michael Tjepkema, Russell Wilkins and Andrea Long

Abstract

Background

People with lower levels of education tend to have higher rates of disease and death, compared with people who have higher levels of education. However, because death registrations in Canada do not contain information on the education of the deceased, unlinked vital statistics cannot be used to examine mortality differentials by education.

Methods

This study examines cause-specific mortality rates by education in a broadly representative sample of Canadians aged 25 or older. The data are from the 1991 to 2006 Canadian census mortality follow-up study, which included about 2.7 million people and 426,979 deaths. Age-standardized mortality rates (ASMRs) were calculated by education for different causes of death. Rate ratios, rate differences and excess mortality were also calculated.

Results

All-cause ASMRs were highest among people with less than secondary graduation and lowest for university degree-holders. If all cohort members had the mortality rates of those with a university degree, the overall ASMRs would have been 27% lower for men and 22% lower for women. The causes contributing most to that "excess" mortality were ischemic heart disease, lung cancer, chronic obstructive pulmonary disease, stroke, diabetes, injuries (men), and respiratory infections (women). Causes associated with smoking and alcohol abuse had the steepest gradients.

Interpretation

A mortality gradient by education was evident for many causes of death.

Keywords

Age-standardized mortality rates, rate differences, rate ratios, socio-economic inequalities.

Authors

Michael Tjepkema (1-613-951-3896; michael.tjepkema@statcan.gc.ca) is with the Health Analysis Division at Statistics Canada, Ottawa, Ontario K1A 0T6. Russell Wilkins is with the Health Analysis Division and the University of Ottawa. Andrea Long is with the Public Health Agency of Canada, Ottawa, Ontario.

The social, economic and environmental conditions that people experience throughout their lives are the most important influences on their health.[1] Known as the *social determinants of health*, these factors include income, occupation, living conditions, and importantly, education.

The level of education that a person achieves is influenced by circumstances that include family income during childhood and intergenerational effects such as the mother's education.[1,2-5] Differences in educational attainment may be associated with different health trajectories. People with lower levels of education tend to have high rates of disease and mortality, compared with those with higher levels of attainment.[6]

Education can affect health through multiple pathways.[6,7] Educational attainment may be an indicator of intra- and inter-personal skills that are needed to produce and maintain good health.[8,9] Health literacy—the ability to access and use health information to make decisions that contribute to the maintenance of basic health—is considered a critical link between education and health outcomes.[10] People with higher levels of education may be more receptive to prevention messages and better able to change their behaviours and to use the health care system effectively.[11] For instance, people with higher levels of education may be less likely to engage in health risk behaviours, such as smoking.[12] Education is also closely connected with other social determinants of health. Higher attainment can increase opportunities for employment and income security,[1] and research consistently documents better health in higher-income groups.[13-15]

The association between education and mortality is well established in western and eastern European countries.[16,17] In Canada, however, death registrations do not contain information about the education of the deceased. As a result, unlinked vital statistics cannot be used to examine differences in mortality by level of education. To overcome this obstacle, several smaller-scale record linkage-based mortality follow-up studies have been conducted.[18-23] These studies demonstrated socio-economic differentials in mortality in Canada, but their applicability may be limited by the scope of the universe covered (geographically, or by age, sex and/or occupation), small sample size, lack of information about causes of death, or a combination of factors.

Recently, a broadly representative sample of Canadian adults aged 25 or older was linked to almost 16 years of mortality data.[24-26] This cohort has been used to examine gradients in all-cause mortality (and life expectancy) by various socio-economic indicators. All-cause mortality rates were shown to be lower in each successively higher category of socio-economic status, whether defined by income, education or occupation. But the cohort has not been used to assess educational gradients in cause-specific death rates. The objective of this study, therefore, is to examine cause-specific mortality rates by level of education to determine if the association between education and mortality differs by cause of death.

Table 1
Educational attainment, by sex and age group, non-institutional cohort members aged 25 or older, Canada, 1991 (baseline)

Sex and age group	Total number	Less than secondary graduation	Secondary graduation	Post-secondary diploma	University degree
			%		
Men					
25 or older	1,358,200	35.0	37.6	12.4	15.1
25 to 44	725,500	24.1	42.7	15.7	17.5
45 to 64	433,400	41.4	34.6	9.9	14.0
65 to 74	135,700	58.0	26.9	6.2	8.9
75 or older	63,600	65.3	22.3	4.9	7.5
Women					
25 or older	1,376,600	34.8	35.2	18.4	11.7
25 to 44	765,100	23.0	40.2	21.5	15.3
45 to 64	388,300	42.7	31.5	16.9	8.9
65 to 74	136,300	59.3	25.9	10.5	4.3
75 or older	86,800	64.2	21.9	10.0	3.9

Source: 1991 to 2006 Canadian census mortality and cancer follow-up study

Methods

The data are from the 1991-to-2006 Canadian census mortality follow-up study, which tracked mortality in a 15% sample of the adult population.[24-26] Respondents to the 1991 Census were eligible to be included in the study cohort if they were: (1) 25 or older and a usual resident of Canada on the day of the census (June 4, 1991); (2) not a long-term resident of an institution such as a prison, hospital or nursing home; and (3) enumerated using the long-form questionnaire that was administered to one in five private households, and to all residents of non-institutional collective dwellings and Indian reserves. Approximately 3.6 million individuals met these criteria.

The electronic 1991 census database does not contain names, which are needed to determine mortality. To obtain names, census records were first linked to tax-filer data from 1990 and 1991 using probabilistic matching, based on dates of birth and postal codes of the individual and his/her spouse or common-law partner (if any). About three-quarters of those who were in-scope were successfully linked to non-financial tax-filer data. The cohort was then linked to the Canadian Mortality Database (June 4, 1991 to December 31, 2006) using probabilistic methods.[27] Even without a match to a death registration, follow-up status (alive, dead, emigrated, or lost to follow-up) could usually be determined from tax-filer data.[25] Overall, the cohort consisted of 2.7 million people, 16% of whom (426,979) died during the follow-up period (Appendix Table A).

Underlying cause of death was coded according to the World Health Organization's *International Classification of Diseases, Ninth Revision*[28] for deaths that occurred in 1991 through 1999, and according to the *Tenth Revision*[29] for deaths that occurred in 2000 through 2006. Deaths were grouped by Global Burden of Disease categories,[30] and by behavioural health risk factors, namely, smoking-related,[16] alcohol-related,[16] and drug-related[31] diseases. Deaths before age 75 that were potentially amenable to medical intervention, such as those due to cerebrovascular disease, hypertension, breast cancer and pneumonia/influenza,[16,32] were also examined.

Highest level of education at cohort inception (baseline) was grouped into four categories: less than secondary graduation, secondary graduation (or trades certificate), postsecondary certificate or diploma (short of a bachelor's degree), and university degree.

For each cohort member, person-days of follow-up were calculated from the day of the census (June 4, 1991) to the date of death, date of emigration or the last day of the study period (December 31, 2006). Person-days of follow-up were divided by 365.25 to obtain person-years at risk. Age-at-baseline-, sex-, and educational attainment-specific mortality rates by 5-year age groups were used to calculate age-standardized mortality rates (ASMRs), using the cohort population structure (person-years at risk), both sexes together, as the standard population.

Relative inequalities were assessed by rate ratios (RRs) and percent excess mortality. RRs were calculated by dividing the ASMR for those with lower levels of education (less than secondary graduation, secondary graduation, or postsecondary diploma) by the ASMR for those with a university degree. RRs greater than 1.00 indicate an increased mortality risk. Percent excess mortality was calculated by subtracting the ASMR for those with a university degree from the ASMR for the total cohort, then dividing by the total ASMR and multiplying by 100.

Absolute inequalities were assessed by rate differences (RDs) and absolute excess mortality. RDs were calculated

by subtracting the ASMR for those with a university degree from the ASMR of those with lower levels of education (less than secondary graduation, secondary graduation, or postsecondary diploma). RDs greater than zero indicate excess mortality. Absolute excess mortality was calculated by subtracting the ASMR of those with a university degree from the ASMR for the total cohort. The difference represents the number of deaths (per 100,000) that hypothetically could have been avoided if all cohort members had experienced the mortality rate of those with a university degree.

Based on previously described methods,[33] 95% confidence intervals for ASMRs, RRs and RDs were calculated.

Results

The percentages of male and female cohort members, respectively, at each level of education were 35% and 35% for less than secondary graduation, 38% and 35% for secondary graduation, 12% and 18% for postsecondary diploma, and 15% and 12% for university degree (Table 1). Younger cohort members tended to have higher levels of education than did older members.

The ASMR for all causes of death showed a clear stair-stepped gradient by level of education, with higher mortality rates for those with lower levels of education. Compared with people who had a university degree, the rate ratio (RR) for those with less than secondary graduation was 1.55 for men and 1.44 for women (Tables 2 and 3).

Table 2
Age-standardized mortality rates per 100,000 person-years at risk for selected causes of death, by educational attainment, male cohort members aged 25 or older at baseline, Canada 1991 to 2006

Cause of death	Total	University degree	Post-secondary diploma	Secondary graduation	Less than secondary graduation	RR	RD	Excess	% excess
All causes	**1,372.8**	**1,008.9**	**1,145.7**	**1,315.2**	**1,561.9**	**1.55***	**553.0***	**363.9**	**26.5**
Communicable diseases	57.1	50.9	49.7	53.0	62.1	1.22*	11.1*	6.2	10.8
HIV/AIDS	5.8	7.4	6.7	5.6	4.7	0.63*	-2.7*	-1.5	-26.5
Respiratory infections	36.4	31.5	30.6	33.9	39.9	1.27*	8.4*	4.9	13.5
Non-communicable diseases	1,188.4	863.8	993.7	1,139.2	1,342.8	1.55*	479.0*	324.6	27.3
Malignant neoplasms	416.5	296.3	353.9	408.3	467.3	1.58*	171.0*	120.2	28.9
Stomach cancer	15.5	9.5	12.4	14.0	18.5	1.94*	9.0*	6.0	38.6
Colon and rectal cancers	44.0	34.3	40.7	43.0	48.0	1.40*	13.7*	9.7	22.0
Liver cancer	9.0	6.6	8.5	8.8	10.0	1.52*	3.4*	2.4	26.9
Pancreatic cancer	19.9	18.6	18.7	20.0	20.9	1.12	2.3	1.3	6.6
Trachea, bronchus, and lung cancers	124.1	55.3	84.3	115.5	154.7	2.80*	99.3*	68.7	55.4
Prostate cancer	51.7	46.2	50.9	51.3	53.0	1.15*	6.9*	5.5	10.6
Diabetes mellitus	38.3	25.0	30.5	34.9	45.6	1.83*	20.6*	13.3	34.7
Neuropsychiatric conditions	65.7	65.4	64.0	63.2	70.4	1.08*	5.0	0.3	0.4
Alcohol use disorders	5.0	2.5	3.4	4.4	7.0	2.82*	4.5*	2.6	50.9
Alzheimer's disease and other dementias	32.9	34.6	32.9	32.5	33.0	0.96	-1.5	-1.7	-5.1
Cardiovascular diseases	483.4	360.3	408.1	459.6	544.3	1.51*	184.0*	123.1	25.5
Ischemic heart disease	293.3	209.5	246.7	279.8	333.5	1.59*	124.0*	83.8	28.6
Cerebrovascular disease	79.3	67.8	65.8	74.6	87.3	1.29*	19.5*	11.5	14.5
Respiratory diseases	86.0	47.2	59.9	76.7	102.5	2.17*	55.3*	38.8	45.1
Chronic obstructive pulmonary disease	65.4	31.1	40.5	56.0	80.3	2.58*	49.2*	34.4	52.5
Digestive diseases	46.5	29.6	34.0	45.5	55.1	1.86*	25.5*	16.9	36.4
Cirrhosis of the liver	15.1	7.7	10.3	15.3	18.8	2.44*	11.1*	7.4	48.9
Injuries	70.2	47.0	54.2	69.3	91.3	1.94*	44.4*	23.2	33.1
Unintentional injuries	45.7	32.1	37.0	45.3	58.2	1.81*	26.1*	13.6	29.8
Road traffic accidents	7.9	5.1	6.4	7.8	10.1	1.98*	5.0*	2.8	35.3
Intentional injuries	24.4	14.8	17.2	24.0	33.1	2.23*	18.3*	9.6	39.2
Suicide	22.7	13.9	16.2	22.6	30.2	2.17*	16.3*	8.8	38.7
Smoking-related diseases	216.2	102.6	143.9	198.3	266.1	2.59*	163.5*	113.5	52.5
Alcohol-related diseases	15.8	7.4	9.6	15.1	21.6	2.90*	14.1*	8.4	53.0
Drug-related diseases	5.4	3.4	3.4	5.5	7.7	2.25*	4.3*	2.0	36.7
Amenable to medical intervention (younger than 75)	51.6	35.9	42.1	48.4	61.0	1.70*	25.1*	15.7	30.5

* significantly different from rate for university degree ($p < 0.05$)
RR = rate ratio (less than secondary graduation / university degree)
RD = rate difference (less than secondary graduation - university degree)
Excess = (total - university degree)
% excess = [100 * (total - university degree)/total]
Note: Reference population (person-years at risk) for age-standardization was taken from internal cohort age distribution (5-year age groups).
Source: 1991 to 2006 Canadian census mortality and cancer follow-up study.

Table 3
Age-standardized mortality rates per 100,000 person-years at risk for selected causes of death, by educational attainment, female cohort members aged 25 or older at baseline, Canada 1991 to 2006

Cause of death	Total	University degree	Post-secondary diploma	Secondary graduation	Less than secondary graduation	RR	RD	Excess	% excess
All causes	**869.4**	**677.7**	**736.6**	**820.9**	**977.7**	**1.44***	**300.0***	**191.7**	**22.0**
Communicable diseases	34.2	27.2	29.0	31.7	39.0	1.43*	11.8*	7.0	20.4
HIV/AIDS	0.5	0.3	0.2	0.5	0.9	3.21*	0.6*	0.2	40.9
Respiratory infections	21.8	17.1	19.1	20.7	23.9	1.40*	6.9*	4.7	21.7
Non-communicable diseases	748.0	581.2	639.4	710.1	835.0	1.44*	253.8*	166.8	22.3
Malignant neoplasms	273.3	231.1	250.1	272.6	294.8	1.28*	63.7*	42.2	15.5
Stomach cancer	6.8	4.8	5.5	6.1	8.0	1.64*	3.1*	2.0	29.4
Colon and rectal cancers	28.0	23.8	26.7	27.9	29.8	1.25*	5.9*	4.2	14.8
Liver cancer	4.3	3.2	4.0	3.8	4.9	1.57*	1.8	1.1	26.1
Pancreatic cancer	14.9	11.0	13.4	15.6	15.5	1.41*	4.5*	3.9	26.2
Trachea, bronchus, and lung cancers	61.7	29.2	45.1	59.3	77.0	2.64*	47.8*	32.4	52.6
Female breast cancer	49.2	57.2	51.1	51.8	46.0	0.80*	-11.2*	-8.1	-16.4
Cervix uteri cancer	3.8	2.3	2.8	3.3	5.3	2.36*	3.1*	1.5	40.5
Ovarian cancer	14.5	15.3	14.9	14.7	14.1	0.92	-1.2	-0.8	-5.9
Diabetes mellitus	24.3	11.6	14.3	18.4	32.1	2.78*	20.5*	12.8	52.5
Neuropsychiatric conditions	55.9	57.3	53.0	55.2	58.5	1.02	1.2	-1.3	-2.4
Alcohol use disorders	1.5	0.8	0.9	1.2	2.3	2.77*	1.5	0.6	43.2
Alzheimer's disease and other dementias	36.7	36.3	35.5	36.5	37.1	1.02	0.8	0.3	0.9
Cardiovascular diseases	280.4	204.3	231.3	258.5	315.6	1.54*	111.3*	76.0	27.1
Ischemic heart disease	142.0	97.1	111.6	129.0	162.5	1.67*	65.4*	44.8	31.6
Cerebrovascular disease	64.0	52.9	57.0	61.6	69.1	1.31*	16.2*	11.1	17.4
Respiratory diseases	42.5	23.6	32.4	37.4	51.2	2.17*	27.6*	18.9	44.4
Chronic obstructive pulmonary disease	30.1	14.2	21.8	25.9	36.7	2.59*	22.5*	15.9	52.9
Digestive diseases	32.3	22.4	24.2	31.4	38.0	1.69*	15.6*	9.9	30.6
Cirrhosis of the liver	7.1	3.8	4.5	6.7	9.6	2.55*	5.9*	3.3	46.8
Injuries	31.2	29.4	30.3	30.2	36.2	1.23*	6.8*	1.9	6.0
Unintentional injuries	24.4	24.0	23.9	23.2	27.9	1.16*	3.9	0.4	1.5
Road traffic accidents	3.5	3.6	3.7	3.2	4.3	1.18	0.6	-0.1	-3.1
Intentional injuries	6.9	5.4	6.4	7.0	8.3	1.55*	3.0*	1.5	21.9
Suicide	6.0	4.5	6.0	6.0	7.1	1.58*	2.6*	1.5	25.6
Smoking-related diseases	100.8	49.7	74.0	94.3	124.2	2.50*	74.5*	51.1	50.7
Alcohol-related diseases	5.7	2.9	3.7	5.6	8.0	2.75*	5.1*	2.8	49.1
Drug-related diseases	4.5	2.6	3.6	4.3	6.9	2.68*	4.3*	1.9	43.0
Amenable to medical intervention (younger than 75)	65.6	58.8	57.6	64.2	72.8	1.24*	14.0*	6.8	10.4

* significantly different from rate for university degree ($p < 0.05$)
RR = rate ratio (less than secondary graduation / university degree)
RD = rate difference (less than secondary graduation - university degree)
Excess = (total - university degree)
% excess = [100 * (total - university degree)/total]
Note: Reference population (person-years at risk) for age-standardization was taken from internal cohort age distribution (5-year age groups).
Source: 1991 to 2006 Canadian census mortality and cancer follow-up study.

The mortality gradient by education differed by cause of death. For men, RRs comparing those with less than secondary graduation to those with a university degree were particularly high for deaths due to trachea, bronchus and lung cancers (RR=2.80), chronic obstructive pulmonary disease (RR=2.58), and cirrhosis of the liver (RR=2.44) (Table 2). By contrast, the gradient was reversed for deaths due to HIV/AIDS (RR=0.63), and not statistically different for pancreatic cancer (RR=1.12) and dementia (RR=0.96).

For women, the RRs comparing those with less than secondary graduation to university degree-holders were notably high for deaths due to trachea, bronchus and lung cancers (RR=2.64), alcohol use disorders (RR=2.77), chronic obstructive pulmonary disease (RR=2.59), and cirrhosis of the liver (RR=2.55) (Table 3). On the other hand, the gradient was reversed for female breast cancer (RR=0.80), and not statistically different for ovarian cancer (RR=0.92), dementia (RR=1.02), and road traffic accidents (RR=1.18).

The education-related percentage "excess" (last column in Tables 2 and 3) shows that if every cohort member had experienced the age-specific mortality rates of those with a university degree, the all-cause ASMR would have been 27% lower for men and 22% lower for women, representing 364 and 192

Table 4
Age-standardized mortality rates per 100,000 person-years at risk for selected causes of death, by educational attainment, age group and sex, cohort members aged 25 or older at baseline, Canada 1991 to 2006

Sex, age group at baseline and cause of death	Total	University degree	Post-secondary diploma	Secondary graduation	Less than secondary graduation	RR	RD	Excess	% excess
Men									
25 to 44									
All causes	211.5	117.6	159.4	216.6	305.6	2.60*	188.0*	93.9	44.4
Unintentional injuries	27.7	11.0	18.6	28.5	44.1	4.01*	33.1*	16.7	60.3
Ischemic heart disease	30.6	14.4	22.7	30.7	47.8	3.31*	33.3*	16.2	52.9
Suicide	23.8	12.5	17.7	25.2	33.2	2.66*	20.7*	11.3	47.5
Trachea, bronchus, and lung cancers	13.1	4.9	8.8	14.5	19.9	4.07*	15.0*	8.2	62.7
45 to 64									
All causes	1,319.3	807.4	1,048.6	1,251.4	1,583.6	1.96*	776.2*	512.0	38.8
Ischemic heart disease	274.6	159.6	224.9	261.8	330.9	2.07*	171.4*	115.1	41.9
Trachea, bronchus, and lung cancers	181.7	72.2	121.6	165.8	239.4	3.32*	167.2*	109.5	60.3
Chronic obstructive pulmonary disease	42.4	12.4	22.1	34.5	59.5	4.79*	47.1*	30.0	70.7
Cerebrovascular disease	51.6	31.5	35.9	48.3	62.8	2.00*	31.3*	20.1	39.0
65 to 74									
All causes	5,304.4	3,923.5	4,320.0	5,058.1	5,775.8	1.47*	1,852.3*	1,380.8	26.0
Ischemic heart disease	1,180.8	818.3	986.6	1,124.4	1,292.8	1.58*	474.6*	362.5	30.7
Trachea, bronchus, and lung cancers	499.5	225.3	327.4	464.1	584.1	2.59*	358.8*	274.2	54.9
Chronic obstructive pulmonary disease	318.9	137.1	166.3	267.9	392.0	2.86*	254.9*	181.8	57.0
Cerebrovascular disease	333.1	266.4	266.1	308.2	364.8	1.37*	98.4*	66.7	20.0
75 or older									
All causes	9,517.4	8,201.0	8,417.8	9,078.8	9,988.4	1.22*	1,787.4*	1,316.4	13.8
Ischemic heart disease	2,187.4	1,844.3	1,896.9	2,083.8	2,304.1	1.25*	459.9*	343.1	15.7
Trachea, bronchus, and lung cancers	568.4	294.6	428.1	516.9	643.7	2.18*	349.1*	273.8	48.2
Chronic obstructive pulmonary disease	594.4	332.8	402.9	523.2	678.8	2.04*	346.0*	261.6	44.0
Diabetes mellitus	247.3	207.9	195.4	227.1	265.2	1.28*	57.3*	39.4	15.9
Women									
25 to 44									
All causes	134.5	87.2	109.6	131.5	193.1	2.22*	105.9*	47.4	35.2
Trachea, bronchus, and lung cancers	13.9	5.2	9.9	14.2	22.6	4.38*	17.4*	8.8	63.0
Ischemic heart disease	6.6	2.5	4.7	6.3	11.5	4.61*	9.0*	4.2	62.6
Unintentional injuries	9.0	5.6	7.9	8.1	14.2	2.52*	8.6*	3.4	37.7
Suicide	6.8	4.2	6.5	6.9	8.5	2.04*	4.3*	2.6	38.5
45 to 64									
All causes	780.9	521.5	616.0	717.0	926.2	1.78*	404.7*	259.5	33.2
Trachea, bronchus, and lung cancers	103.4	42.6	71.9	97.3	131.2	3.08*	88.6*	60.8	58.8
Ischemic heart disease	89.9	33.7	56.1	79.1	118.0	3.50*	84.3*	56.2	62.5
Chronic obstructive pulmonary disease	27.8	6.8	17.4	20.0	39.8	5.83*	33.0*	21.0	75.4
Diabetes mellitus	24.0	8.3	12.9	17.5	34.3	4.11*	26.0*	15.6	65.2
65 to 74									
All causes	3,198.6	2,493.2	2,660.5	2,993.8	3,446.1	1.38*	952.9*	705.4	22.1
Ischemic heart disease	571.8	396.0	408.0	505.6	645.5	1.63*	249.4*	175.8	30.7
Trachea, bronchus, and lung cancers	196.6	100.8	155.7	187.3	216.0	2.14*	115.2*	95.8	48.7
Chronic obstructive pulmonary disease	146.7	62.8	99.6	126.9	170.8	2.72*	108.0*	83.9	57.2
Cerebrovascular disease	250.9	188.0	218.8	241.4	266.1	1.42*	78.1*	62.9	25.1
75 or older									
All causes	6,420.2	5,682.1	5,740.0	6,151.6	6,694.0	1.18*	1,011.9*	738.1	11.5
Ischemic heart disease	1,350.0	1,105.5	1,165.4	1,244.3	1,439.5	1.30*	334.0*	244.5	18.1
Chronic obstructive pulmonary disease	228.7	144.6	181.9	219.2	246.6	1.71*	102.0*	84.1	36.8
Diabetes mellitus	171.9	103.2	107.3	131.5	203.2	1.97*	100.0*	68.7	40.0
Trachea, bronchus, and lung cancers	179.3	124.0	144.1	177.2	190.4	1.54*	66.5*	55.3	30.9

* significantly different from rate for university degree ($p < 0.05$)
RR = rate ratio (less than secondary graduation / university degree)
RD = rate difference (less than secondary graduation - university degree)
Excess = (total - university degree)
% excess = [100 * (total - university degree)/total]
Note: Reference population (person-years at risk) for age-standardization was taken from internal cohort age distribution (5-year age groups).
Source: 1991 to 2006 Canadian census mortality and cancer follow-up study.

fewer deaths per 100,000, respectively. ASMRs for trachea, bronchus and lung cancers, diabetes mellitus (women), chronic obstructive pulmonary disease, and alcohol use disorders (men) would each have been at least 50% lower.

The causes of death contributing the most to education-related absolute excess mortality (next-to-last column in Tables 2 and 3) were ischemic heart disease, lung cancer, chronic obstructive pulmonary disease, cerebrovascular disease, diabetes, injuries (men), and respiratory infections (women). Together, these seven causes accounted for about two-thirds of the total education-related excess mortality for men (65%) and women (64%) (percentages not shown).

RRs for smoking-, alcohol- and drug-related disease deaths all exceeded 2.00 (Tables 2 and 3). ASMRs for smoking- and alcohol-related diseases would have been about 50% lower if all cohort members had experienced the age-specific mortality rates of cohort members with a university degree.

For deaths potentially amenable to medical intervention, the gradient in mortality by education was less steep (RR=1.70 for men and 1.24 for women). The percent excess was 31% for men and 10% for women.

The gradient in RRs by education was steepest in the youngest age group (25 to 44 at baseline) and less steep in each successively older age group (Table 4). For men, the RRs were 2.60 at ages 25 to 44 and 1.22 at age 75 or older. For women, the RRs were 2.22 at ages 25 to 44 and 1.18 at age 75 or older. Although RRs across levels of educational attainment were highest in younger age groups, absolute differences were greatest in older age groups (among whom most deaths occur).

The causes of death that contributed the most to excess mortality differed by sex and age group. Among cohort members aged 25 to 44 at baseline, unintentional injuries was the largest contributor to excess mortality for men, and cancer of the trachea, bronchus and lung was the largest contributor for women. For both sexes aged 45 to 74, ischemic heart disease and lung cancer were the two largest contributors to excess mortality. For those aged 75 or older, ischemic heart disease was the largest contributor, followed by chronic obstructive pulmonary disease for women and lung cancer for men.

Discussion

This analysis shows important differences in cause-specific mortality rates by level of education. For most causes of death, the higher the level of educational attainment, the lower the mortality rate, which is broadly consistent with European[11,16] and American[8,9,34] research. Compared with university degree-holders, people with less than secondary graduation had age-standardized mortality rate ratios of 1.55 for men and 1.44 for women. If the entire cohort had experienced the age-specific mortality rates of those with a university degree, the all-cause ASMR would have been 27% lower for men and 22% lower for women. Extrapolated to the total non-institutional adult population, that equates to an estimated 50,000 fewer deaths per year: 33,000 among men and 17,000 among women. A similar reduction in mortality could have been achieved if all ischemic heart disease and cerebrovascular disease deaths had been eliminated.

Among the causes of death that contribute the most to absolute excess mortality, cardiovascular diseases (including ischemic heart disease and cerebrovascular disease) consistently rank as the most costly in terms of health care system use and lost productivity due to morbidity and premature mortality. Respiratory illnesses such as chronic obstructive pulmonary disease are also among the top five with respect to the direct and indirect economic burden of illness.[35,36]

In terms of RRs, causes of death closely associated with health risk behaviours (for instance, smoking and excessive alcohol consumption) tended to have a steeper mortality gradient by education than did causes not as strongly associated with those behaviours. This is consistent with research indicating that people in lower socio-economic categories are more likely to engage in health risk behaviours.[15,37-39]

The current study revealed greater relative inequalities at younger than at older ages. It has been suggested that a selection effect may be operating at older ages: individuals with lower socio-economic status may die earlier, so that only the healthiest survive into old age, leading to reduced socio-economic inequalities in mortality.[11] It is also possible that the decrease in relative risks

Why is this study important?

- The reduction of socio-economic inequalities in health outcomes is an explicit objective of health policies in Canada.
- Understanding socio-economic inequalities by cause of death may help achieve this objective.

What is already known on this subject?

- All-cause mortality rates are higher for people with relatively low levels of educational attainment.

What does this study add?

- If all cohort members had experienced the age-specific mortality rates of those with a university degree, the age-standardized mortality rate would have been 27% lower for men, and 22% lower for women.
- For both sexes, the causes of death contributing most to that "excess" mortality were ischemic heart disease, lung cancer, chronic obstructive pulmonary disease, stroke, diabetes, injuries (men) and respiratory infections (women).

may be partly explained by attenuation of the association between risk factors and chronic diseases in old age.[40] However, absolute differences in mortality rates were larger in older age groups (65 to 74 and 75 or older) than in younger age groups. Thus, reduction in mortality inequalities at older ages would have the greatest impact on reducing the number of education-related excess deaths.

Strengths and limitations

The large sample on which this study is based is broadly representative of all Canadian adults, and allowed for analysis of mortality differences (in relative and absolute terms) by education within detailed cause of death groupings.

This study was not intended to assess the relative importance of direct and indirect effects of education on mortality: for example, to what extent could educational differences in mortality be explained by associated differences in income?

The data did not include information on risk factors (such as smoking), and thus, might overestimate the effect of education on mortality. Nevertheless, other research concludes that socio-economic differences in various health outcomes (including mortality) largely persist even after controlling for behavioural risk factors.[7,41,42] Further research to determine the degree to which individual behaviours and risk factors explain (or fail to explain) the higher mortality rates experienced by persons of lower socio-economic status in Canada would require long-term mortality follow-up from health surveys that collect data on behavioural risk factors and on indicators of socio-economic status.

This analysis was based on the credentials cohort members had attained by June 4, 1991. Since then, Canadians have become more educated, so the percentage of the population in the lowest attainment levels has declined. This would reduce education-related excess mortality, assuming that the relative risks remained unchanged. However, while this study provides baseline data on the nature and extent of education-related inequalities in mortality, it cannot determine if those inequalities have persisted, increased or decreased over time. Only future linkages of mortality data to more recent censuses (or to the National Household Survey) can provide the data needed to assess such changes.

Conclusion

This study demonstrates important differences in mortality rates by level of education for most causes of death. Causes more closely associated with health risk behaviours tended to have a steeper gradient in mortality by education than did causes not as strongly associated with those behaviours. These results build on previous research by providing evidence by cause-specific groups, and confirm the existence of a consistent gradient in mortality by education across most causes of death. With the extension of the 1991-to-2006 Canadian census mortality follow-up study to include linkage to cancer data, future work could examine the nature and extent of educational inequalities in cancer incidence and survival. ■

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Appendix

Table A
Cohort members aged 25 or older, person-years at risk, and deaths ascertained, by age group and educational attainment at baseline, by sex, Canada, 1991 to 2006

	Men			Women		
Age group and educational attainment	Cohort members	Person-years at risk	Number of deaths	Cohort members	Person-years at risk	Number of deaths
Total 25 or older						
Less than secondary graduation	474,900	6,249,140	138,071	478,500	6,563,790	110,472
Secondary graduation	510,400	7,318,980	69,084	484,000	7,096,100	47,128
Postsecondary diploma	168,300	2,457,660	15,493	253,000	3,734,390	19,960
University degree	204,600	2,942,760	18,339	161,100	2,379,250	8,432
25 to 44						
Less than secondary graduation	175,000	2,616,330	8,066	176,200	2,651,730	5,243
Secondary graduation	309,800	4,649,830	9,981	307,200	4,649,350	6,010
Postsecondary diploma	113,700	1,708,250	2,690	164,600	2,487,060	2,654
University degree	127,000	1,868,330	2,330	117,100	1,749,410	1,516
45 to 64						
Less than secondary graduation	179,600	2,484,030	43,532	165,700	2,402,990	24,071
Secondary graduation	149,900	2,144,350	25,829	122,400	1,810,250	12,369
Postsecondary diploma	43,100	625,240	5,949	65,500	975,020	5,482
University degree	60,800	888,540	6,268	34,700	517,610	2,342
65 to 74						
Less than secondary graduation	78,700	851,130	48,956	80,800	1,015,830	35,470
Secondary graduation	36,500	415,050	20,772	35,300	459,080	13,749
Postsecondary diploma	8,400	99,940	4,213	14,300	189,510	5,051
University degree	12,100	147,970	5,649	5,900	79,360	1,986
75 or older						
Less than secondary graduation	41,500	297,650	37,517	55,700	493,230	45,688
Secondary graduation	14,200	109,760	12,502	19,000	177,410	15,000
Postsecondary diploma	3,100	24,220	2,641	8,700	82,800	6,773
University degree	4,800	37,930	4,092	3,400	32,880	2,588

Note: Cohort member counts rounded to nearest 100, person-years at risk to nearest 10.
Source: 1991 to 2006 Canadian census mortality and cancer follow-up study.